Chapter 8
Free-Product Recovery

8-1. General

Chemical contaminants usually existing as free product and methods of removal are described in the first section of the chapter. The chapter's second section is a hazard analysis with controls and control points listed.

8-2. Technology Description

a. Compound Types.

Many contaminants, usually hydrophobic organics, when released in sufficient volume, will exceed the absorption capacity of the intervening soils and flow down to the groundwater surface through the soil pore spaces. If less dense than water, the materials will float on the groundwater, slightly depressing the surface tension in a potentially recoverable pool. If denser than water, the materials will continue to sink through the pore spaces (displacing water), forming discrete and connected ganglia, and later possibly reaching a lower retarding layer.

The most prevalent classes of compounds likely to exist as free product or non-aqueous phase liquids (NAPLs) are those compounds with low solubilities in water such as chlorinated solvents, reagents (e.g., trichloroethylene, tetrachloroethylene, and PCBs), and petroleum hydrocarbons (e.g., gasoline, jet fuel, fuel oils, and tars). Chlorinated solvents and tars are typically more dense than water and are called DNAPL (dense non-aqueous-phase liquids). Petroleum hydrocarbons are generally less dense than water and are called LNAPL (light non-aqueous-phase liquids). DNAPLs tend to sink vertically. They will often migrate deep underground into isolated areas where it may be impossible to remove them by conventional treatments. LNAPLs float on the water table and tend to spread laterally at the top of the capillary fringe.

b. Removal Methods.

Free product, such as oil or NAPLs, on groundwater may be removed using three methods:

- Open trenches.
- Back-filled trenches with recovery wells.
- Extraction wells.

Water table depth and gradient are the primary factors in selecting a recovery method. Schematics of one-pump and two-pump recovery well systems are presented in Figures 8-1, 8-2, and 8-3.

Making any free-phase product recovery system effective requires a good understanding of geologic conditions. Limitations on the rate of recovery include water, free-phase handling capabilities, and site-specific factors.

Recovery trenches can be used to remove LNAPL when the groundwater depth is shallow enough to reach with a trench. LNAPL recovery devices can be installed into the trench to recover free product. A groundwater pump may be used to depress the local groundwater and increase the rate of oil and water flow to the trench. An impermeable barrier or barriers (e.g., bentonite or clay slurry wall) can be installed to divert liquid flow towards the trench.

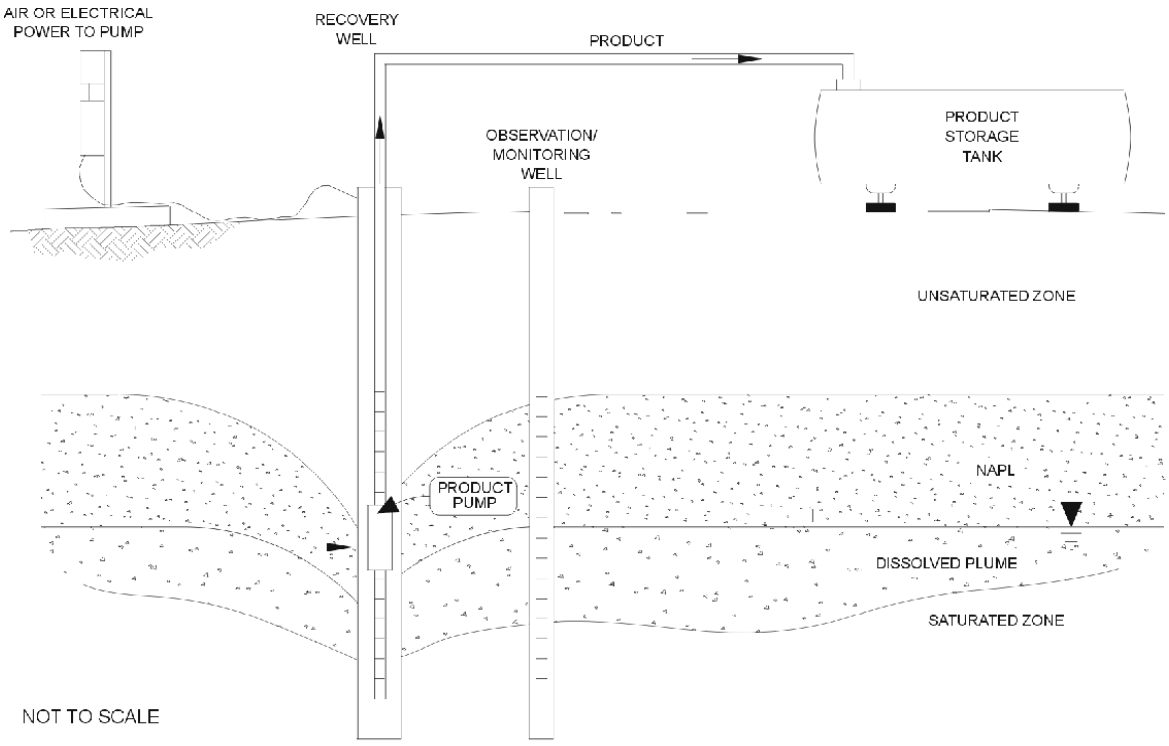

FIGURE 8-1. FREE-PRODUCT RECOVERY(ONE-PUMP SYSTEM)

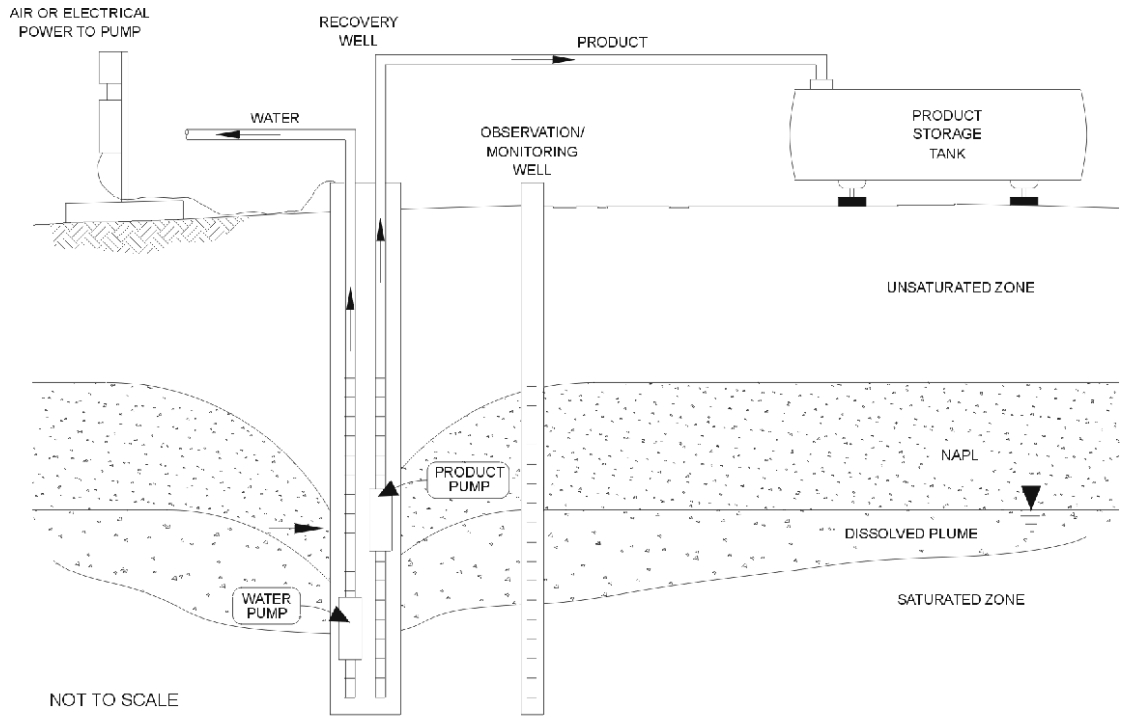

FIGURE 8-2. FREE-PRODUCT RECOVERY(TWO-PUMP SYSTEM)

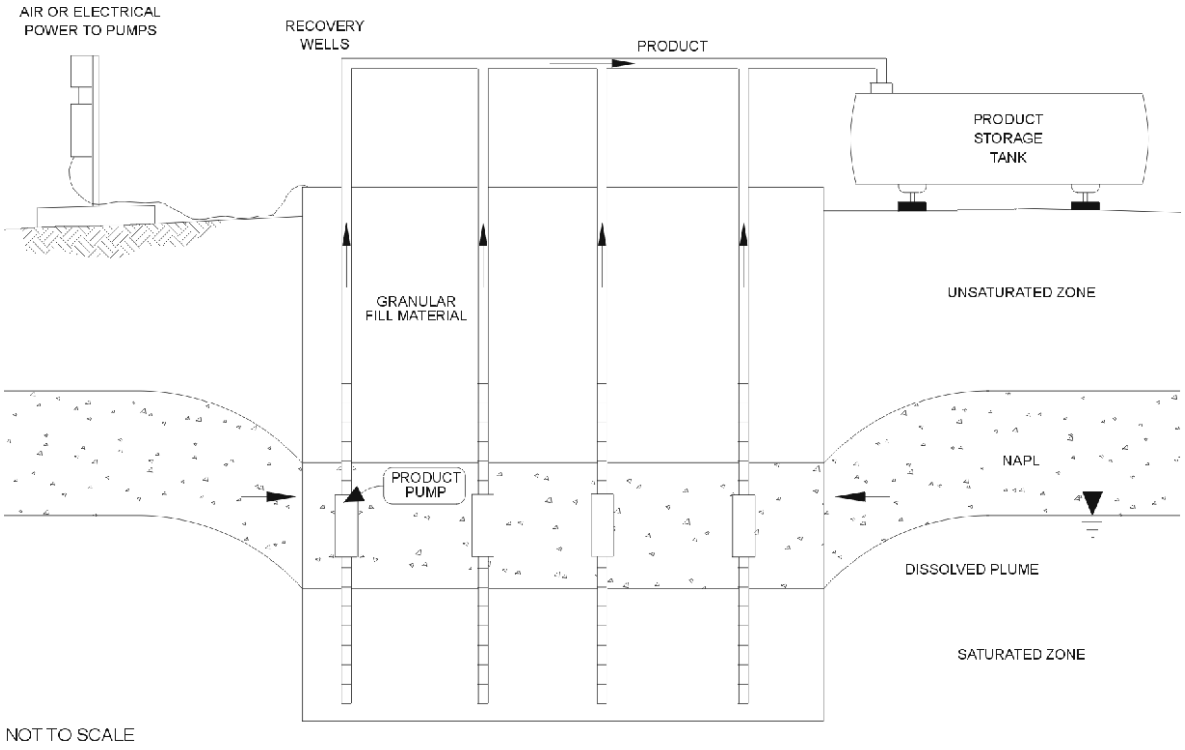

FIGURE 8-3. FREE-PRODUCT RECOVERY TRENCH

Extraction (recovery) wells also may be used. Slurry walls can be used to guide the groundwater and product flow to the well or wells. LNAPL in the well can be removed with a product skimmer pump or belt skimmer, vacuum devices (slurpers), or a groundwater recovery pump. A groundwater pump creates a cone of depression, which can increase the oil recovery rate, but can also emulsify water and LNAPLs. Recovery wells can be single pump, double pump, or double shaft. A single-pump well uses one pump to recover oil and water. Double-pump wells combine a product recovery pump with a groundwater drawdown pump into a single well. A double-shaft well uses two concentric casings in one well. Free product is recovered in the outer casing while groundwater is drawn down by another pump in the inner casing. This separation of devices allows better regulation of water level and flow within the well, and helps minimize emulsion of oil and water.

For DNAPL recovery, the pool of sinking product must be located (if present); the lower retarding strata must be delineated for low points where the DNAPL has flowed; and those low points must be penetrated by recovery wells and pumps to capture NAPL. This is usually a slow process, but may be enhanced by groundwater recovery and re-injection with or without surfactants.

8-3. Hazard Analysis

Principal unique hazards associated with free-product recovery, methods for control, and control points are described below.

a. Physical Hazards.

(1) *Fire or Explosion Hazards (Drilling).*
Description. Soil boring using hollow-stemmed augers prior to well installation may cause a fire or explosion during drilling into soils saturated with flammable or combustible materials under unusual or extraordinary conditions. Sparks generated when an auger contacts rocks, metal, or other underground objects may ignite a flammable atmosphere inside the borehole. This is considered an unlikely but potential hazard.

Control. Controls for fire or explosion hazards include:

- Train operators in the hazards of drilling into or through flammable liquids or materials.
- Train operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures including extinguishing flames, extracting, extinguishing and stabilizing victims, and in emergency drill system isolation and shutdown procedures.
- Use mud or water rotary drilling methods, which add moisture to the cutting area.

CONTROL POINT: Construction, Maintenance

(2) *Utility Contact Hazards*.
Description. Fire, explosion, or electrocution hazards may exist when using hollow-stemmed auger drilling methods if the rotating auger contacts or ruptures underground utilities (electrical or gas lines) or comes in contact with overhead electric lines.

Control. Controls for utility contact hazards include:
- Train the operators in the hazards of drilling in the vicinity of underground or overhead utilities.
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures for electrocutions, burns, and extinguishing flames, extracting, extinguishing and stabilizing victims, and in emergency drill system isolation and shutdown procedures.
- Contact local utilities and public works authorities to determine the locations of all utilities. When there is any doubt or uncertainty, perform a utility survey, probe with a metal rod, or hand excavate to determine the exact location of utilities prior to drilling. Once utilities are located, careful drilling may be allowed.
- Post an observer to the side to supervise when raising a drill mast.
- Do not move the drilling rig with the mast raised.

CONTROL POINT: Design, Construction, Maintenance

(3) *Fire and Explosion Hazards (Transfer of Flammable Liquid).*
Description. During the transfer of flammable or combustible liquids (such as jet fuel) from the recovery well, a fire or explosion hazard may exist. The liquid may be ignited by improperly selected or installed equipment. Emissions from the collection equipment may also be ignited, possibly causing a fire or explosion. Ejector pumping systems produce mixtures of flammable vapors and air, which may ignite and explode.

Control. Controls for fire and explosion hazards include:
- Train the operators in the hazards of the collection system, including the reactivity of the contaminants extracted, and the sources of ignition including static electricity.
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures including extinguishing flames, extracting, extinguishing and stabilizing victims, and in emergency recovery system isolation and shutdown procedures.
- Verify that the hazardous area classifications, as defined in NFPA 70 Chapter 5, sections 500.1 through 500.10, are indicated on the drawings.
- Use controls, wiring, and equipment in conformance with the requirements of EM 385-1-1, Section 11, and NFPA 70 for the identified hazard areas.
- Check electrical system design and equipment installation for appropriateness to hazard areas.

- Use grounded equipment or equipment provided with ground fault circuit interrupter (GFCI) protection if required by EM 385-1-1 or NFPA 70.
- Do not use piping systems and ejectors that mix air with flammable vapors.

CONTROL POINT: Design, Construction, Operations, Maintenance

(4) *Equipment Hazards*.
Description. During installation of the extraction trenches, workers may be seriously injured or killed by heavy equipment such as front-end loaders and backhoes. Heavy equipment may also generate elevated noise levels, which may damage worker hearing.

Control. Controls for equipment hazards include:
- Use heavy equipment with a backup alarm to alert workers.
- Provide spotters for the equipment operators.
- Provide workers in the vicinity of operating heavy equipment with fluorescent orange or lime green traffic vests.
- Approach operating equipment from the front and within view of the operator, preferably making eye contact.
- Wear hearing protection.

CONTROL POINT: Construction, Maintenance

(5) *Trench Hazards*.
Description. Walls of trenches used for free-product recovery may collapse, causing workers to fall into the excavation.

Control. Controls for trench hazards include:
- Ask a competent person to determine the integrity of the excavation before workers are allowed to walk near the edge of the excavation.
- Do not approach the edge of the excavation without fall protection.
- See EM 385-1-1, Section 25, for additional control measures and requirements.

CONTROL POINT: Design, Construction, Maintenance

(6) *Confined Space Hazards*.
Description. Depending on the dimensions, trenches can create confined space conditions where workers may be overexposed to airborne chemical hazards if the atmosphere in the confined space contains a toxic chemical, such as flammable liquid vapors or chlorinated solvent vapors, or is otherwise oxygen deficient.

Control. Controls for confined space chemical hazards include:
- Train workers in confined space hazards and on safety procedures to employ in confined space entry.
- Design the confined space to maximize natural ventilation.

- Develop a pre-entry confined space permit. Implement a confined-space entry program to assess hazards, including air testing the space interior both prior to and throughout the work planned (see 29 CFR 1926.21).
- Ventilate confined spaced if a hazardous atmosphere exists.
- If the space is filled with flammable vapors, eliminate all potential sources of ignition prior to and during occupancy.

CONTROL POINT: Operations

(7) *Unguarded Moving Equipment*.
Description. Skimmer belts used for free-product removal from trenches are often equipped with unguarded pulleys, which may cause entanglement of body parts or loose clothing.

Control. Controls for moving equipment include:
- Use only guarded pulleys and guarded moving or rotating mechanical devices.
- Train workers to operate the equipment only with the machine guarding in place.
- Disallow the wearing of loose clothing near the equipment.

CONTROL POINT: Design, Construction, Operations, Maintenance

(8) *Fire or Explosion Hazards (Tanks)*.
Description. Containment tanks used for storage of recovered free product may overflow, creating the potential for fire or explosion.

Control. Controls for tanks include:
- Train the operators in the hazards of the collection tank system, including the reactivity of the contaminants extracted, and the sources of ignition, including static electricity.
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures including extinguishing flames, extracting, extinguishing and stabilizing victims, and in emergency recovery system isolation and shutdown procedures.
- Install fluid level indicators equipped with automatic shut-off switches on free-product recovery tanks to help prevent overflowing.
- Inspect the collection equipment regularly to identify and repair system leaks.

CONTROL POINT: Design, Operations, Maintenance

(9) *Steam Pressure Washing*.
Description. Steam pressure washing of equipment may expose workers to thermal, burn or injection hazards, eye hazards from flying projectiles dislodged during pressure washing, slip hazards from wet surfaces, and noise hazards.

Control. Controls for steam pressure washing include:

- Use insulated gloves (e.g., silica fabric gloves) and keep all body parts away from the ejection point of the stream pressure discharge nozzle.
- Wear safety goggles and hearing protection.
- Wear slip-resistant boots.
- Equip washers with deadman or kill switch if not provided by manufacturer.
- Drain water away from the decontamination operation into a tank or pit.
- Drain walking surfaces and keep free of standing liquids or mud.

CONTROL POINT: Construction, Operations, Maintenance

(10) *Respirable Quartz Hazard.*

Description. Depending on soil types, exposure to respirable quartz may be a hazard during trench excavation. Consult geology staff to confirm the presence of a respirable quartz hazard (e.g., to determine if soil types are likely to be rich in respirable quartz). As an aid in determining respirable quartz exposure potential, sample and analyze site soils for fines content by ASTM D422 (R2002): "Standard Test Method for Particle Size Analysis of Soils" followed by analysis of the fines by X-ray diffraction to determine crystalline silica quartz content.

Control. Controls for respirable quartz include:

- Wet soil periodically with water to minimize worker exposure. Wetting of soil may require additional controls to deal with resulting water, ice, mud, etc. Consult 29 CFR 1910.1000, Table Z-3, to calculate acceptable respirable dust concentrations based on percent silica in the quartz.
- Use respiratory protection, such as an air purifying respirator equipped with N, R or P100 particulate air filters.
- Train workers in the potential inhalation hazards of crystalline silica dust exposures.

CONTROL POINT: Design, Construction, Operations, Maintenance

(11) *Muscle Injuries.*

Description. Manual lifting of heavy objects may expose workers to back, arm, and shoulder injuries.

Control. Controls for muscle injuries include:

- Do not require workers to lift heavy loads manually.
- Use proper lifting techniques including stretching, bending at the knees, and bringing the load close to the body prior to lifting (see EM 385-1-1, Section 14). Utilize more than one worker to manage the lift.
- Use mechanical lifting equipment to lift or to move loads.

CONTROL POINT: Design, Construction, Operations, Maintenance

(12) *Emergency Wash Equipment.*
Description. Emergency shower/eye wash equipment required per 29 CFR 1910.151 is not always provided with adequate floor drains, thereby creating potential electrical hazards and walking surface hazards during required testing and use.

Control. A control for emergency wash equipment includes:
- See American National Standards Institute ANSI Z 358.1 – 1998: "Emergency Eyewash and Shower Equipment" for design requirements.
- Equip showers/eye wash equipment with accompanying functional drains to isolate and collect the shower/eye washwater from unprotected electrical equipment and walking surfaces that, when wet, create slipping and electrical hazards.

(13) *Design Field Activities.*
Description. Design field activities associated with subsequent construction may include surveying, biological surveys, soil gas surveys, geophysical surveys, trenching, drilling, stockpiling, contaminated groundwater sampling, and other activities. Each of these field activities may expose the survey personnel to physical, chemical, radiological, and biological hazards.

Control. Controls for hazards resulting from design field activities include:
- Prepare an activity hazard analysis for design field survey activities. EM 385-1-1, Section 1, provides guidance on developing an activity hazard analysis.
- Train workers in hazards identified.

CONTROL POINT: Design

b. Chemical Hazards.

(1) *Vapor Discharge.*
Description. Vapors discharged from oil/water separators may expose workers to VOCs via inhalation.

Control. A control for vapor discharge includes:
- Vent the discharge from the oil/water separators into the ambient environment above and beyond the breathing zone of workers.

CONTROL POINT: Design

(2) *Chemical Exposure.*
Description. Process and equipment piping for the collection, transfer, treatment, and storage of recovered free product may leak and create an exposure

pathway by ingestion/inhalation/dermal contact for workers operating or maintaining the system. Workers may be exposed to waste materials, such as benzene in gasoline or other hydrocarbons in jet fuel. The exposure may cause skin, eye, and respiratory tract irritation and other symptoms.

Control. Controls for chemical experience include:

- Prevent leaks through regular system inspection and maintenance.
- Detect leaks by a regular leak detection process using O_2 meters, explosivity meter, PIDs, OVA, leak detection fluids, and other appropriate methods.
- Wear personal protective equipment (PPE) such as an air-purifying respirator with organic vapor cartridges and nitrile gloves for exposure to the free products such as jet fuel or gasoline.

CONTROL POINT: Operations, Maintenance

(3) *Contaminant Exposures (Trench/Well Installation).*
Description. During trench or well installation, workers may be exposed to contaminants, such as VOCs, dusts, and metals in soil and development water through the three exposure routes of inhalation/ingestion/dermal contact.

Control. Controls for contaminant exposures include:

- Apply water or an amended water solution to the area during well and trench installation to help control the generation of airborne dusts, particulates, and VOCs.
- Use respiratory protection including an air-purifying respirator equipped with approved filter/cartridges such as N, R or P100 particulate air filters, organic vapor (OV) cartridges for vapors, or combination filter/cartridges for dual protection.
- Analyze work tasks and potential for chemical exposure to determine the correct PPE and respirator cartridges. The analysis should include a chemical waste profile to help ensure that PPE specified will be appropriate for the respective chemical hazards.

CONTROL POINT: Construction, Operations, Maintenance

(4) *Contaminant Exposures (Free-Product Recovery and Collection).*
Description. During operation of the free-product recovery trenches and collection equipment, workers may be exposed to chemical materials, such as jet fuel, hydrogen sulfide, VOCs, and biologically generated byproducts (e.g., vinyl chloride, methane).

Control. Controls for contaminant exposures include:

- Wear respiratory protection (e.g., an air-purifying respirator with organic vapor cartridges or supplied air, depending on adequacy of the warning properties – hydrogen sulfide and vinyl chloride exhibit poor warning properties) to control inhalation exposures to VOCs during operation of collection equipment.

- Analyze the type of respirator required before issuing PPE. Include a chemical waste profile on the waste materials to ensure that the respirator and filter/cartridge or air supply specified will be appropriate.

CONTROL POINT: Operations, Maintenance

c. Radiological Hazards.

Radioactive Materials.
Description. Radioactive materials may have been buried or naturally occurring radioactive material (NORM) may be present in soils, sludge, and groundwater. Radioactive materials may become entrained with the free product and eventually build up as scale in pipes and handling systems. Some radioactive materials may present an external exposure hazard. All radioactive materials may present an internal exposure hazard through inhalation or ingestion. Exposure to radiation using this remediation technology may be rare.

Control. Controls for radioactive materials include:
- Test soil, sludge, or groundwater to determine if radioactive materials are present.
- Consult a qualified health physicist if any radioactive material above background levels is found to determine exposure potential and any necessary engineered controls or PPE.

CONTROL POINT: Design, Construction, Operations, Maintenance

d. Biological Hazards.

No unique hazards are identified.